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VINEYARD TRIALS IN CALIFORNIA WITH NEMATODE-RESISTANT GRAPE ROOTSTOCKS[1]

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INTRODUCTION

PLANT PARASITIC nematodes are recognized today as important destructive pests of all the cultivated varieties of the grape species, *Vitis vinifera*. In recent years the significance of these pests to the viticultural industry of California has been emphasized, particularly in the lighter and warmer soils of the irrigated interior valleys.

The plant parasitic nematodes found on grapes are microscopic worms which live in or upon the root systems and injure the roots through their feeding. A number of important parasitic nematode species have been associated with injured and dying grape roots. Research is currently underway to further describe these nematodes, their distribution, and the extent of injury they can cause on susceptible grapevines. Of these nematodes, the root-knot nematodes (*Meloidogyne* spp.) are probably the most widely spread and of the greatest economic importance to the grape industry in California. They are easily recognized in the field by the characteristic symptoms they produce on the roots of the grapevines.

Grafting the desired fruiting variety of grapes upon a nematode-resistant rootstock variety has for years been used as an effective means of controlling the damage done by these parasites. Over nearly the past one hundred years the numerous native wild American grape species and their hybrids have been intensively studied for their suitability as rootstocks. This interest has been centered principally upon their resistance to phylloxera (*Dactylasphaera*) and their adaptability to soil conditions such as tolerance to drought, to high limestone soils or their ability to grow under wet summer soil conditions. Only in the last thirty years has interest been directed toward the study of nematode resistance of the native American grapes and their suitability as rootstocks for nematode-infested California vineyards.

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REVIEW OF LITERATURE

As knowledge of the destructive capacity of parasitic nematodes to the root systems of susceptible plants has expanded, their importance to the grape industry of California has been realized. Premature vine decline, weakening of vegetative growth, and a rapid and great decrease in production are commonly noted when grapevines are established on light sandy soils infested with nematodes. Allen (1951)[3] describes the array of plant parasitic nematodes found in the agricultural areas of California and emphasizes the economic importance of a number of these species to the production of grapes.

Bessey (1911) was, however, the first in this country to draw attention to the widespread nature of root-knot nematode infestations. He had compiled an extensive list of susceptible plant species and a few tolerant or resistant ones. Among the resistant types, Bessey noted that certain phylloxera-resistant grape hybrids and some pure species showed near immunity to root-knot nematodes. Ten years prior to Bessey's publication Lavergne (1901) had noted that the European varieties of grapes (*Vitis vinifera*) growing in a limited area of Chile were very susceptible to root-knot nematode attack. On the other hand, those varieties of American origin, which were commonly used elsewhere in the world for their resistance to phylloxera were also resistant to nematode pests. The stocks of principal interest in Chile at that time, according to Bessey, were seedling selections of the species *V. riparia* and *V. rupestris*.

The first published report of resistance in *Vitis* species, as well as their suggested use as rootstocks for commercial vineyards, was that of investigations in Florida by J. C. Neal (1889). He described specifically the heavy incidence of injury on *vinifera* grapes and those of the *Aestivalis* group. He also stated "... but when these vines were grafted into stocks of the *Cordifolia* or *Vulpina* races they have made superb growth free of the disease." This then is the earliest report of nematode resistance in *Vitis* species as well as of their suggested use as rootstocks for this purpose.

It was in 1936, however, that the first comprehensive study was made in California of the commercial possibilities of nematode-resistant grape material. Snyder (1936) examined 154 varieties of *Vitis vinifera* as well as a large number of other grape species selections and hybrid rootstocks in soils infested with root-knot nematodes. This work was conducted in the San Joaquin Valley at two locations, one near Shafter and the other near Fresno. Results of Snyder's studies showed that all *V. vinifera* varieties were heavily infested, that most of the species and rootstocks of American origin were, also, but that a few did show moderate to high resistance. Among the latter were Solonis × Othello 1613, Solonis × Riparia 1616, *V. doaniana*—Salt Creek, and three *V. champini* selections: Dogridge, Barnes, and DeGrassett. The grape species of greatest experimental interest found in this work were: *Vitis Solonis, V. champini,* and *V. doaniana.* Snyder's work thus laid the foundation for the future nematode rootstock investigations in California.

It is obvious from this survey of published reports that a considerable amount of nematode resistance exists within some of the species of *Vitis*. A

[3] See "Literature Cited" for citations referred to in the text by author and date.

commercial grape rootstock variety must, however, possess merits beyond its tolerance to a soil-borne pest. Its behavior in the nursery and its effect on the fruiting habits of the scions grafted upon it are also of prime consideration. In order to study the various viticultural characteristics of potential rootstock varieties, it is necessary to follow the stocks through trials established as grafted plants under commercial vineyard conditions. The first test of this nature was established at Fresno in 1932 by Snyder and Harmon (1948). This trial, involving nine rootstocks and ten scion varieties, showed that over a thirteen-year period of growth several of the phylloxera- and nematode-resistant stocks were capable of vigorous growth and good fruit production. The best in performance among these were Solonis × Othello 1613 and *V. champini* Dogridge.

The results of a second experiment at Fresno were published by Harmon and Snyder (1952), in which three stocks, Solonis × Othello 1613, *V. champini* Dogridge, and *V. rupestris* St. George were compared when grafted to 17 scion varieties. This trial was established on a medium sandy loam near Fresno which was infested with both grape phylloxera and root-knot nematodes. The results of this study pointed up the vigorous growth of *V. champini* Dogridge. The stock Solonis × Othello 1613 showed average vigor with good fruit production while the performance of *V. rupestris* St. George was considerably below either of the other stocks.

A third report by these authors, Harmon and Snyder (1956), compared the same three stocks with the scion variety Thompson Seedless. The vines in this trial were located in an experimental planting near the town of Shafter. The soil, of a light sandy nature, was stated to be heavily infested with root-knot nematodes (*Meloidogyne* spp.). After nine years of growth in this trial, *V. champini* Dogridge and Solonis × Othello 1613 were again found to be the outstanding stocks, both giving excellent yields and vigorous vine growth.

It is important to note that the field trials cited above were established at a time when limited information was available on the array of plant parasitic nematodes now known to attack grapevines in the soils of the interior valleys of California. However, since the trials were established in soils of types commonly used for vineyards and were placed in locations known for nematode infestation, they did yield very useful information on the relative behavior of the rootstocks included.

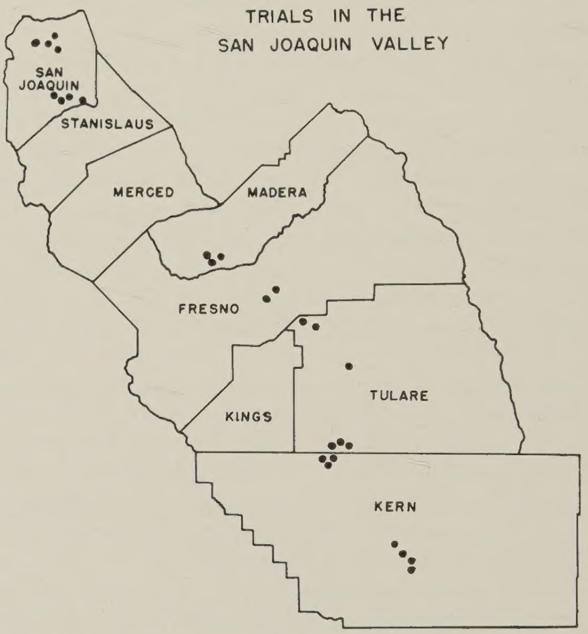
COÖPERATIVE EXPERIMENTAL TRIALS

The information gathered in the San Joaquin Valley with the early experiments on nematodes and nematode-resistant grape varieties provided a background for the current phase of rootstock investigations. Studies conducted by Tyler (1933) had increased the interest in nematode control and pointed to the potential danger of the pests to the industry. The results of grape rootstock studies by Husmann (1910), as well as the efforts of Snyder and Harmon (1936, 1948, 1952, 1956) which were underway at the time formed the basis for the choice of stocks and the testing procedures adopted by the Department of Viticulture and Enology of the University of California. During the years between 1935 and 1945 numerous test plots were placed in

the vineyard districts of California by the late Professor H. E. Jacob,[4] in order to evaluate further the field performance of promising nematode-resistant stocks. These trials were established through the interest and coöperation of commercial growers, in commercial plantings in the grape districts of the state and with the assistance of the extension personnel of the counties in which the trials were placed. The locations were confined to the San Joaquin Valley and some parts of southern California where environmental conditions favored the development of high populations of plant

Fig. 1

DISTRIBUTION OF ROOTSTOCK TRIALS IN THE SAN JOAQUIN VALLEY



parasitic nematodes. In general these were in the light sandy soils and in sites which had demonstrated vine deterioration through root-knot nematode injury to own-rooted plantings. The choice of scion variety was left to the grower and in most instances was the same as that used in the remainder of the vineyard in which the trial occurred.

The results of the earlier studies on nematode-resistant stocks indicated that a few of the chosen stock varieties were worthy of further field tests. It was felt that by establishing widely distributed field trials, a broad range of soil and other environmental conditions could be examined, several scion varieties studied, and the effects of varying cultural practices understood in comparing the final performance of the rootstocks chosen.

The primary function of trials of this nature was to gather reliable data on the relative performance of the important fruiting varieties when grown on various rootstocks. In addition, since many of the trials were set out in

[4] Harry E. Jacob, Associate Professor of Viticulture and Associate Viticulturist in the Experiment Station, initiated the present phase of research on grape rootstocks and contributed materially to its progress until his untimely death in 1949.

localities where own-rooted vines were used predominantly, they often not only demonstrated the need for, but also the utility of rootstocks in general. Also, since many of the tests were in areas where the use of grafted vines is not common, they acquired the added function of acquainting growers with the essential principles involved in establishing and maintaining vineyards of grafted vines.

Figure 1 is an outline map of the counties of the San Joaquin Valley, an area including the major portion of the grape plantings in California. Each dot on this map indicates the approximate location of one of the experimental trials in a commercial vineyard. The majority of these trials were located in the areas around Lodi in San Joaquin County, in Fresno and upper Tulare counties, and in Kern County. In addition, two trials not shown on the map were located in the grape district west of San Bernardino in southern California.

In general, the districts in which these trials were located are represented by fertile sandy or sandy loam soils. Frequent summer irrigation is practiced and heavy-yielding wine, raisin, and table grape varieties are commonly grown. Plant parasitic nematode infestations are known to occur generally throughout the area shown in figure 1 (Allen, 1951). They, however, are found doing serious damage in grape plantings most frequently only in the light, loose, sandy locations. For this reason most of the experimental plantings were placed in the sandier portions of the coöperating growers' vineyards, and in sites known to be capable of supporting high populations of nematodes. Frequently these trials were placed as replant vines in areas where the own-rooted vines had failed.

The rootstocks which were chosen for use in the experimental trials are given in the following list: *V. solonis* × Othello 1613; *V. solonis* × *V. riparia* 1616; Dogridge, *Vitis champini;* Salt Creek, *Vitis champini; V. berlandieri* × *V. riparia* 5–A; and *V. berlandieri* × *V. riparia* 420A.

The stock 1613[5] is known as a complex hybrid. Although the exact origin of this stock is obscure, usually its parentage is given as a cross between a seedling of the grape species *Vitis solonis* (also known as *Vitis longii*) and the variety Othello. Othello is a hybrid, itself, combining *V. labrusca, V. riparia,* and *V. vinifera.* Husmann (1910) in his descriptions of grape investigations in California identified it as a hybrid grown by Couderc, and listed it in plantings made in several test areas in California as early as 1903. Viala (1909), however, does not list it in his dictionary of grape species and varieties. Its vigorous growth, high nematode resistance, and excellent performance shown in the earlier rootstock tests described above made it a first choice in these coöperative trials. At the time the trials were established, considerable grower interest had developed in the use of nematode-resistant stocks. Many vineyard plantings had appeared which included the stock 1613 in either experimental- or commercial-sized blocks. Today, 1613 is widely used in the interior valleys and is one of the few nematode-resistant stocks available from commercial nurseries in California.

The stock 1616 is a hybrid of the species *V. solonis* (*V. longii*) and *V. riparia.* Reported to have been produced by Couderc prior to 1900 (Viala,

[5] Abbreviated names for the stocks will be used throughout the remainder of this report.

1909), it is noted for its lime tolerance and ability to withstand drought conditions. It is considered to carry some phylloxera resistance. Husmann (1910) initiated trials with 1616 in California as early as 1903. In his tests he rated it as moderately vigorous, and quite suitable on heavy, wet soils. Since it performed well in the screening trials for root-knot nematodes conducted by Snyder (1936), it was included in the list of stocks to be tested.

Dogridge is a very vigorous seedling of the species *Vitis champini*. The species, *V. champini*, however, is described as being a population of plants of hybrid origin, arising through intercrossing of *V. candicans* and *V. rupestris* (Viala and Ravez, 1896). Regardless of its origin, Dogridge is very resistant to nematodes and carries some phylloxera resistance. In the light sandy soils of the warm grape-growing regions it produces extremely strong-growing scions. Dogridge was selected by T. V. Munson prior to 1900 (Viala, 1909), as a promising, vigorous grafting stock for use in vineyards in the southeastern portion of the United States.

Salt Creek is another stock selected by T. V. Munson. It is listed by Viala (1909) as having originated as a seedling of *V. doaniana*. The variety used in these coöperative test plots under this name, however, does not appear to be the same as that described by Viala. Its type of growth, leaf, and fruit characteristics are closer to those of *V. champini* than to *V. doaniana*. The selection used is a vigorous-growing stock, quite resistant to nematodes.

The two *V. berlandieri* × *V. riparia* hybrids selected for inclusion in these tests are both only moderately tolerant to nematodes. They were originally selected for European conditions with special note given to their phylloxera resistance and ability to grow in vineyard soils of high limestone content. The stock 420A was created by Millardet and released for general use in France in 1889. The related hybrid, 5–A, was produced in Hungary by A. Teleki and released in 1897. It soon became popular in many vineyard districts of Europe. Though 5–A is only moderately tolerant of nematodes, its relatively great vigor makes it capable of growing well on some of the less-fertile, sandy, nematode-infested soils.

Not all of the six stocks discussed above appeared in each of the trial plantings. The nature of the location, the growers' desires, the scion variety chosen, and the availability of planting space determined the choice of rootstocks as well as the number of vines of each which were planted. Since stock 1613 was being used extensively in commercial plantings it was decided to include it in each of the rootstock tests and to consider it as the standard for comparison of the other experimental stocks.

The plots, as shown in figure 1, were established in the various districts of the valley more or less randomly as the opportunity arose to set out trials. The first was placed in Tulare County in 1935 and the last to be considered in this report, in Madera County in 1944. A few of the trials indicated in figure 1, however, will not be considered in detail in this report. Since the test plots were widely scattered throughout the state, close supervision of the grower maintenance on each was often impossible. In addition, several of them were established as replants in mature vineyards and often in the poorest section of the grower's plantings. A degree of vine mortality and lack of uniformity in the trial could be expected. When this occurred before sufficient records could be obtained for an accurate comparison of the stocks,

the trial was abandoned. Frequently, even though complete summaries could not be made of the data gathered on trials of this sort, they did furnish valuable observations which could serve as a guide in evaluating the performance of the stocks in the other more complete tests.

Each trial in this study consisted of one scion variety grafted upon one or more rows of each of the rootstock varieties, each row consisting of from 15 to 40 vines. In some instances bench-grafted vines were furnished to the grower at the time the trial planting was set out; in most cases, however, the rootstock vines were grafted in the field by the grower or by the field personnel of the Department of Viticulture and Enology.

Records showing initial conditions of the stand, the replants furnished, and the success in establishing the young vines were taken annually on the trials during the first four years. When the vines had matured to the point of giving commercial yields, usually at four or five years of age, the gathering of detailed annual records on the trial was begun. The manner of gathering and analyzing the fruit samples and of making yield estimates and vigor measures are described in a discussion of similar studies on phylloxera-resistant rootstocks (Lider, 1958).

In the trials reported upon here which were grafted to raisin varieties, yield records were obtained by counting the number of raisin trays placed in the vineyard rows at harvest; in the trials grafted to wine-grape varieties, the yields were gathered either by box counts or by weighing the fruit at harvest, and when this was not possible by crop estimates carefully made on the individual vines prior to harvest. The crop in the trials handled for shipping fruit was often harvested over an extended period, the grower frequently removing fruit from the vines several times as the crop matured. Thus yield data at harvest were very difficult to obtain. In these cases cluster counts were made on the individual vines in the trials. These counts were then used to calculate the yields from the average cluster weight obtained on the fruit sample.

The trunk-circumference measurement represents a terminal measurement made on the vines in each of the trials. This was obtained by averaging the last three years of the record taken on the trial. As in the trials previously reported upon (Lider, 1958), annual summaries of the data on vine vigor, yield, and fruit quality were prepared for each trial. Finally, summaries of these annual data were made which included all the years that fruit samples had been taken from each of the trials. These summaries are presented at the end of this paper in tables 1 through 19. The title to each of these tables gives the scion variety used in the trial, the year, the county of California in which it was established, and the inclusive years of the summarized records. The footnote to each gives the location, soil type, source of scion wood, and other pertinent information on the establishment of the trial.

The order in which the stocks occur in each of these field trials is the same as the arrangement of stocks in each of the respective tables. No predetermined arrangement was used. Since the trials were established over a period of several years, a nearly random order of stocks in the trials does exist.

A survey of the root-knot nematode species occurring in a portion of these field trials was conducted in 1959. Although a number of the trials had been uprooted prior to this date, enough were still standing to offer a chance to

study the ability of species within the nematode genus *Meloidogyne* to reproduce on the different rootstocks used in these trials and to determine the types of root-knot nematodes which might occur in the test locations. In September of that year root samples were gathered from four rootstocks in each of the trials in which Thompson Seedless occurs as the scion variety. The stocks chosen were 1613, Dogridge and Salt Creek, in addition to the own-rooted vines. Seven trials were still standing and available for sampling from the nine which were originally established. The root samples were preserved in a 1:9 formalin-water solution as they were gathered. These were later examined for the presence of adult female root-knot nematodes and the species determinations made upon these females. The results of this survey are listed below. Included with the name of the nematode species identified on the different rootstocks are the number of the corresponding field trial as well as the county in which each of these Thompson Seedless trials occurs.

Trial 1	Tulare County	1613	*Meloidogyne arenaria thamesi*
		Dogridge	*Meloidogyne arenaria thamesi*
		Salt Creek	*Meloidogyne arenaria thamesi*
		Own Roots	*Meloidogyne arenaria thamesi*
Trial 3	Kern County	1613	*M. incognita*
		Dogridge	none detected
		Salt Creek	none detected
		Own Roots	*M. incognita*
Trial 4	Tulare County	Dogridge	*M. arenaria thamesi*
		Salt Creek	none detected
Trial 5	Kern County	1613	*M. javanica*
		Dogridge	*M. javanica*
		Salt Creek	none detected
		Own Roots	*M. javanica*
Trial 6	Kern County	1613	*M. incognita*
		Dogridge	none detected
		Salt Creek	none detected
		Own Roots	*M. incognita*
Trial 8	Madera County	1613	*M. arenaria thamesi*
		Dogridge	*M. arenaria thamesi*
		Salt Creek	none detected
		Own Roots	*M. arenaria thamesi*
Trial 9	Madera County	1613	*M. arenaria thamesi*
		Dogridge	none detected
		Salt Creek	*M. arenaria thamesi*
		Own Roots	*M. arenaria thamesi*

This survey shows that at least three root-knot species exist on the vines in these widely scattered field trials in the San Joaquin Valley. Significance may be attached to the fact that *Meloidogyne arenaria thamesi* was found to occur on the *Champini* stocks Dogridge and Salt Creek, whereas the other two species found, *M. incognita* and *M. javanica,* did not occur on these stocks. All three nematode species were found to infest the roots of 1613 and the own-rooted Thompson Seedless vines. On the other hand, the vigor of the Dogridge and Salt Creek vines in trials 1, 4, 8, and 9 does not seem to be lowered by the presence of this infestation.

It is logical to assume, at this point, that the ability of the nematode population to reproduce on the roots of the stocks does not in itself indicate that the stock will be materially weakened by the parasites' activities. This is especially true, if the infestation is determined solely on the basis of the presence or absence of reproducing females and does not take into account the total population of parasites present or at least an estimate of the eventual buildup of nematodes which might occur in this environment.

Trials with Thompson Seedless as the Scion Variety. The first nine of these trials (the number of the table will also be used to designate the corresponding field trial), the data of which are presented in tables 1 through 9, were all grafted to the scion variety Thompson Seedless (Sultanina). This variety, a very popular one heavily planted in the San Joaquin Valley, is used extensively for both raisin production and wine making, and to ship fresh as table fruit. When the vines of this variety are handled for shipping fruit, they are trellised rather high, the crop is often hand-thinned, and the vines are usually girdled soon after the clusters complete bloom. These rather special cultural practices could markedly alter the performance of this variety on the various rootstocks. The data from the tests presented in tables 1, 5, and 6 were from vines handled in this manner. The soil types of these three tests are described as deep and fertile, crop yields are well below the potential of vines in locations of this type, as well, the larger average cluster and berry size reflect the girdling and thinning treatments performed on these vines. The other six tests were in plantings in which the fruit was grown for wine or raisin production. In these, the soil types upon which the tests occur are somewhat variable, tending more toward the deep loose sands of low water-holding capacity and lower fertility. Vine vigor is less than in the tests handled as table fruit. Yields also tend to be lower, especially on the less vigorous rootstocks 1613 and 420–A. In test plot 8, for example, though planted in 1938, the trunk circumferences on these two stocks are considerably smaller than trunk circumferences on the same stocks in the other plots. On the other hand, the more vigorous growing stock, Salt Creek, in this trial has given one of the highest yields of any stock in any of the nine test plots grafted to the Thompson Seedless variety.

Table 20 gives a comparison of the measurements of vigor and yield on the stocks in seven of these trials with the scion Thompson Seedless. In the other two trials several of the experimental stocks do not occur. These trials were therefore not included in this summary table. The high vigor of the two *champini* stocks, Dogridge and Salt Creek, can be seen from this table. They have produced vines with trunks consistently larger than the other three stocks considered. On the other hand, this vigor has not been expressed in a corresponding higher yield. The production on Salt Creek, though somewhat higher than the other stocks, is not statistically significant, and that from Dogridge is the lowest of the stocks considered here. As table 20 shows, the yields on the less vigorous rootstock 1613 have been above the average in most of these trials.

The measures on cluster size and average berry weight for the fruit produced on each of these stocks are summarized in table 21. The low yields obtained with Dogridge can be explained from the data in this table. The

cluster size obtained with vines on this stock is somewhat less than average for the nine tests and the berry size is markedly lower. This reduction in berry size more than offsets the added fruiting potential of the more vigorous vines. On the other hand, the berry size and cluster size obtained with the vines on Salt Creek have been quite satisfactory. Again, the less vigorous 1613 has given excellent-sized clusters and well-formed berries. The performance of this rootstock in a number of these tests, especially on soils of fair to good fertility, has produced vines which have been the nearest to that condition desired by growers for quality fruit production.

Trials with Wine Varieties as the Scion. An additional five trials in this series of experiments were established with wine grape varieties as scions. The results from these are given in summary tables 10 through 14. Except for table 10, these trials were all on quite sandy, low-fertility soils; in addition, rather heavy summer irrigations were used, except in trial No. 14, which was located in San Bernardino County. In this case, no irrigation was used in the early years of the test, and only light irrigation in the more recent years. In all trials, except No. 13, the vines were head-pruned. This is a severe pruning system which does not favor the strong growth of the more vigorous stocks. In trial No. 13, the vines were pruned to a cordon system. The high yields on the stock Salt Creek, in this test, reflect the fruiting capability of this vigorous rootstock variety.

Table 22 presents the average yield and vigor measurements on the rootstocks in the five trials with wine grapes. A significant difference exists between the trunk measures of the scions on the five rootstocks considered here. The vigorous stocks Dogridge and Salt Creek are consistently the largest in the trials. Some of the variability between the individual trials can be attributed to the small measurements obtained from trial No. 12. This trial, one of the last to be established, was on extremely sandy, low-fertility soil heavily infested with root-knot nematodes. The trunk circumferences are markedly smaller than those measured in plot No. 10, which was planted only one year earlier. The measures on cluster size and berry weight in these same five trials are presented in table 23. Satisfactory cluster size and berry size were obtained on all stocks, except on the rather weak growing stock 420–A. In general, the differences in berry size and cluster size as noted in this table would have little effect on the final quality of the fruit produced for wine-making purposes and thus would be of little consequence as long as it did not reflect a reduction in total yield of fruit from the vines. The figures in these two tables do not include the results from trial No. 14. This trial, located in San Bernardino County, was not sampled consistently and the crop-yield data were gathered on only a few years. The soil conditions and level of nematode infestations in the location of this test do exemplify the rather difficult grape-growing conditions in this region. The results in both vigor and high yields on Dogridge and Salt Creek are quite striking.

With the 14 trials discussed above, small and generally inconsistent differences were found in the quality of the fruit produced on the different rootstocks within an individual trial. With the wine-variety trials and those of Thompson Seedless handled for raisin production, the berry size, berry color, total soluble solids, and total acidity of the fruit were commercially acceptable on all stocks in each of the trials. A delay in maturity, however, was

noted in some years with Dogridge and Salt Creek in the Thompson Seedless trials handled for table-fruit production. This could be considered a serious drawback.

Trials with Table Varieties as the scion. An additional five trials were established with varieties which are used for fresh-market fruit. The results obtained from these trials are summarized in tables 15 through 19. Four different scion varieties were included. Evaluation of fruit quality in the varieties used is quite difficult and the quality characteristics vary considerably with variety. Small differences in berry size, shape, or color in cluster density or size, as well as in uniformity of appearance between clusters, are quite important factors in determining the quality of the marketable fruit. Thus, comparisons among these four tests are somewhat difficult to make. On the other hand, as in the trials discussed previously, certain patterns of performance can be noted. The stocks Dogridge and Salt Creek again produce, consistently, the largest vines. Crop yields do not vary considerably between rootstocks since some fruit thinning was practiced annually in these trials. The crop, in most years, was, therefore, reduced well below the maximum that vines on soils of the type described were capable of bearing. The yields obtained on the Emperor plot shown in table 19, however, indicate that little or no thinning was done in this trial. The tests with the scion variety Tokay, summarized in tables 17 and 18, show that the berry size, as indicated from the average berry weights, was markedly reduced when Dogridge was used as a rootstock. The fruit produced on Dogridge in the two trials was more intensely colored and tended toward a darker shade than that on the other stocks. Both of these characteristics reduced the market quality of the fruit. The closely related stock Salt Creek, however, did not show these tendencies in trial No. 17. In the other three table-grape trials the cluster size and berry size on these two vigorous stocks were quite satisfactory for the varieties concerned.

In all five of these tests rootstock 1613 showed a more moderate growth, as indicated by the trunk measurements, than the two stocks discussed above. The cluster and berry weights show, however, that good-quality fruit was produced on this stock. Except with the variety Tokay on Dogridge, no consistent difference could be found in the shade or quantity of color produced by the scions on the different rootstocks. The sugar and acid contents showed only minor differences. In some years the less vigorous rootstocks 1613 and 420–A showed a tendency toward a more uniform and earlier maturity of the fruit. This is a desirable character since high-quality and early-maturing fruit will in general command the higher prices.

DISCUSSION OF ROOTSTOCK PERFORMANCE

The vineyards of the interior valleys of California are grown upon a very wide range of soil types. The deeper, heavier, and more fertile soils, however, usually produce the most vigorous vines which bear the heaviest crops. A number of plant parasitic nematode species have been found associated with deteriorating grapevines throughout the interior valleys, the root-knot nematode (*Meloidogyne* spp.) being the most common and the easiest to recognize on the roots of grapes (Allen, 1951).

Plantings of raisin and wine grape varieties most frequently occupy the

poorer vineyard locations—that is, soils of a sandy nature frequently low in fertility and low in water-holding capacity. It is in situations of this type that the own-rooted vines are most subject to nematode attack. As the vine succumbs to the nematode attack upon its roots, its top growth is reduced. As a result of reduced vigor a large number of fruitful buds are formed on the fruiting wood of the weakened vine and thus an excessively heavy crop of fruit is likely to result the following year. A heavy crop combined with a continued nematode attack is likely to cause severe overcropping and a marked extension of the vine's general deterioration. Crop-thinning is generally not practiced in wine and raisin grape vineyards; therefore, frequently localized areas of weakened, overcropped vines can be found in the more sandy, nematode-infested portions of the own-rooted vineyards in most of the grape-growing districts of the interior valleys. Under these conditions the use of the strong growing *champini* stocks, Dogridge and Salt Creek, has been found to be of advantage.

In general, the vineyards for the production of table fruit in the San Joaquin Valley are located on the deeper, more fertile vineyard soils. Crop-thinning is the usual practice, ample irrigation water is carefully applied, and a well-conducted program of cultural care is usually practiced by the growers. High-quality shipping fruit is often the primary production aim rather than large quantities of ordinary fruit. Under such conditions the great vigor and growth potential of the rootstocks Dogridge and Salt Creek are not essential to good vine growth. In fact, with present cultural practices they frequently are found to be adverse in their effects on yield, this resulting from their excessive vigor which reduces both the number and size of the clusters formed by the scion varieties.

On the other hand, rootstock 1613 is more moderate in its influence on the growth habits of its scions. The vigor of the vines produced upon this rootstock in the table grape trials was much nearer to that which the growers are accustomed to handling. Also, since the crop in most table grape vineyards is thinned rather heavily, the total production capacity of the vines is not of great consequence. Those factors determining fruit quality—berry size, shape, and color; cluster size and density; and the sugar and acid balance of the fruit at maturity—are of importance. The table fruit produced on the more moderate growing stocks, such as 1613, as indicated above, has been easier to handle in the vineyard and generally of a higher quality at harvest than that produced on the more vigorous growing stocks.

On the basis of the experimental data gathered from the 19 field trials discussed in this paper, from numerous field observations, as well as from opinions drawn from the experience of commercial growers, the following comments on the performance of the rootstocks considered in this report are timely.

Solonis × Othello 1613. This hybrid rootstock is well adapted to the fertile sandy and sandy-loam soils of the San Joaquin Valley. During the past thirty years its use has been extended widely over the vineyard districts of this area. Table-fruit varieties grafted upon Solonis × Othello 1613 have grown with moderate vigor and the characteristics of the fruit produced have been generally good. In the less-fertile soils, vines grafted upon 1613 have frequently had insufficient vigor and, as a result, have been low in productivity.

Moderate phylloxera resistance has been attributed to this rootstock; the plant has grown well in vineyards in the San Joaquin Valley where the insect is found. From past experimental results, the rootstock has been labeled as carrying a high resistance to plant parasitic nematodes (Snyder, 1936). The results of more recent research have shown instances of its susceptibility to some nematode populations. Until further experimental evidence is gathered, however, it can be considered sufficiently resistant to those strains of root-knot nematodes commonly found on own-rooted grapevines to perform satisfactorily throughout the interior valleys of California.

As with other rootstocks, this stock in recent years has been closely associated with some of the common virus diseases known to be of serious consequence to California vineyards. This is especially true of 1613, with the leafroll virus in the plantings of the table variety Emperor in the mid-San Joaquin Valley (Goheen, 1959). Since this rootstock is a nearly symptomless carrier of this as well as other virus diseases, it has been difficult to eliminate the infected individuals from blocks of nursery-mother vines used for establishing the planting stock for grafted vineyards. In addition, when a vineyard planting of rootstocks carrying a residue of the virus in some of the vines is grafted with scions in which the virus can also occasionally be found, the proportion of mature vines carrying the disease is materially increased since either source, stock or scion, will cause the grafted vine to become infected. Instances of late maturity, low acidity, and poor fruit coloring have been reported with vines grafted upon 1613. Today, these adverse results can be attributed to the presence of virus diseases transmitted by the mother vines and not to the direct influence of the rootstock, itself. With the supply of certified disease-free planting stock which has recently been made available to the growers of the state, virus diseases should not be a future problem.

Rootstock cuttings of 1613 root readily in the nursery and can be easily grafted to all the common fruiting varieties grown in California. Until a better stock is found, 1613 will continue to be widely used in the state. It appears to be generally the most useful rootstock, especially for table grapes, grown on the more fertile, root-knot-nematode-infested soils.

Dogridge (*Vitis champini*). This rootstock variety, selected as a seedling from the wild grape species, *V. champini*, has been studied for its suitability as a rootstock in California vineyards for nearly sixty years. In the warm grape-growing regions and especially in the hot, sandy nematode-infested soils of the interior valleys, it has produced the most vigorous grapevines of any of the rootstocks tested. Because of the great vigor displayed by the scions, vines grafted to this stock have a potential for heavy yields. However, the vigorous growth of the scion on this strong-growing rootstock has generally resulted in shy bearing, particularly during the early life of the vineyard. In sandy soils of low fertility the vine growth of the scions has been more moderate and the crop yields obtained are from fair to good.

One of the major difficulties encountered with Dogridge has been the expression in the scions of little leaf (zinc deficiency) symptoms. This has further accented the shy bearing tendencies of the scion varieties. Recent observations on vines grafted to Dogridge, however, have indicated that carefully managed cultural practices of applying zinc fertilizer, pruning less severely to increase the amount of fruiting wood on the vines, and reducing

the amount of irrigation water used during the summer were quite effective in improving the yields (Lider, 1959). Dogridge is described as having a high resistance to root-knot nematodes and a moderate tolerance to phylloxera. The high nematode resistance of this rootstock is evidenced by its excellent growth characteristics in all of the field trials. Most of these trials were known to contain heavy populations of root-knot nematodes at the time they were established and some of these in recent years were shown to contain several other species of plant parasitic nematodes known to be associated with deteriorating grapevines.

A serious drawback of this stock is the fact that its cuttings root with difficulty in the nursery. Once rooted, however, it can be easily grafted to all common *vinifera* scion varieties.

Dogridge will no doubt find its place in the industry as a choice for replanting those portions of the vineyards which have demonstrated the inability of vines on their own root, or those grafted on other rootstocks, to prove profitable. It is doubtful that high-quality table fruit can be generally produced on this stock, especially when the vines are grown upon the more fertile soils. On the other hand, it appears suitable as a grafting stock for heavy-producing wine and raisin grape varieties on the poorer soils.

Salt Creek (*Vitis champini*). As indicated above, this rootstock appears to be misnamed. The true Salt Creek variety, described by Husmann (1910), is listed as being derived from the species *V. doaniana*. The selection used here has fruit and vine characteristics which more closely resemble those of seedlings of the species *V. champini*. Attempts to positively identify this rootstock have thus far been unsuccessful. Until this is done, however, the name Salt Creek will continue to be used.

This rootstock has demonstrated a high resistance to root-knot nematodes in the field trials. Vines grafted upon it are vigorous. In most instances, however, its scions have not grown quite so strong as those on Dogridge but generally much more so than those on 1613. As with Dogridge, where excessively vigorous growth has been found, zinc deficiency has resulted in the production of poor crops. When this difficulty has been alleviated, however, good crops of quality fruit have been obtained.

Cuttings of Salt Creek root with great difficulty in the nursery, though once rooted they can be readily grafted to the common fruiting varieties.

When the excessive vine growth of scions grafted upon this stock has been controlled by cultural practices its performance with wine and raisin varieties has been quite satisfactory. It can be recommended for limited use with these varieties on the lighter, less-fertile soils, and should be included in any experimental rootstock plantings in nematode-infested soil.

Solonis × Riparia 1616. This hybrid rootstock is described as being quite resistant to root-knot nematodes (Snyder, 1936). It has been tested in field trials in California for many years (Husmann, 1910), but has not been widely used by the growers of the state. Like the more widely used stock 1613 it displays a moderate resistance to phylloxera. Where it has been tested in field trials with wine varieties it has occasionally done fairly well (tables 10, 12, and 13). In sandy-loam soils it has produced scions of moderate vigor with good crops of high-quality fruit. In the less-fertile and sandier soils it has

been weak and undependable in the yields which its scions produce. The stock 1616 has shown considerable promise with Zinfandel in the Lodi area in San Joaquin County. This stock, therefore, should be included in trial plantings of rootstocks in that district.

Berlandieri × Riparia 5–A. This hybrid rootstock, produced in Hungary over sixty years ago, has seen very little use in California. Snyder did not include it in his screening trials. However, field observations on plantings in nematode-infested soils in recent years indicate that it does carry a moderate tolerance to those strains of root-knot nematodes commonly found on grapes in the interior valleys. This rootstock was originally selected for its use in phylloxerated vineyards with soil of high limestone content. It was used rather widely in some parts of Europe for this purpose in the early part of this century. The stock 5–A is relatively vigorous and has produced, in some situations, scions which have been strong and productive.

Its tolerance to nematodes appears to be sufficient to allow it to grow well in the more-fertile sandy soils. In the test plots it has appeared promising with the variety Thompson Seedless when handled for raisin production (tables 2 and 6). Because of the occasionally good results obtained with this stock, it should be included in additional trials in the nematode-infested soils of California.

Berlandieri × Riparia 420–A. This hybrid is one of the old lime-tolerant rootstocks developed and used in Europe. It is noted for its phylloxera resistance and has been grown successfully on vineyard soils extremely high in calcium content—that is, up to 45 per cent or 50 per cent limestone. It does not possess great vigor, however, and its lime tolerance is of no use in the interior valleys of California. Snyder (1936) included this stock in his early trials and found it to be only moderately tolerant to root-knot nematodes. Its performance in the trials reported upon in this paper has not been satisfactory. The reduced growth of its scions and the frequent evidence of serious nematode injury to its roots make it impossible to recommend it for further testing in California.

SUMMARY

Plant parasitic nematodes are recognized today as important pests of grapevines in California. Declining vigor of the vine, reduction of yield, and various types and degrees of root destruction have all been associated with infestations. Most of the vineyard areas on sandy soils in the San Joaquin Valley and southern California are infested to some degree.

Though the common fruiting varieties grown in California are quite nematode susceptible some of the native species of grapes of the southeastern portion of the United States possess inherent resistance to these pests. From these species, notably, *Vitis champini*, *V. solonis*, and *V. berlandieri*, nematode-resistant grape rootstocks have been developed.

Grape rootstock studies in California vineyard areas during the past sixty years by the Department of Viticulture and Enology of the College of Agriculture, University of California, and by the United States Department of Agriculture have established a basis for the coöperative field trials of a limited number of nematode-resistant rootstocks.

The results of twenty-two years of observations on 19 coöperative field trials are presented. These trials were placed in nematode-infested vineyard sites widely scattered throughout the interior valleys and in the grape-growing area in southern California.

Summaries of the data gathered on these trials show that vigorous root-stocks are available, which display a high degree of nematode resistance. These stocks are capable of producing heavy yielding scions in the sandy, low-fertility, nematode-infested vineyard areas.

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TABLE 1

SUMMARY OF RECORDS, 1942–1953, FOR ROOTSTOCK TRIAL IN TULARE COUNTY WITH THE VARIETY THOMPSON SEEDLESS PLANTED IN 1937*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
1613	27.9	30	16.0	546	178	16.5	0.83
Dogridge	33.3	29	13.9	474	136	16.4	1.12
Salt Creek	32.7	25	13.1	507	153	17.4	1.03
1613	28.1	34	16.6	483	158	16.9	0.90
420-A	29.4	34	16.4	477	154	15.8	0.95
1616	30.4	31	15.0	471	158	16.4	1.02
Dogridge†	29.7	29	11.7	426	141	17.2	0.94
Salt Creek†	33.3	25	12.0	526	148	17.7	0.98

* This trial is located about 3½ miles east of Highway 99 just north of the road separating the counties of Kern and Tulare. The soil, mapped as Hanford sandy loam is deep and quite fertile. This trial is placed in an older planting, vines moderately infested with nematodes being pulled to provide space for the test. Rootings of the experimental stocks were provided to the grower by the Department in February, 1937, and field-budded, using scions obtained locally to the variety Thompson Seedless, in August of that year.

† Planted in 1939.

TABLE 2

SUMMARY OF RECORDS, 1943–1952, FOR ROOTSTOCK TRIAL IN TULARE COUNTY WITH THE VARIETY THOMPSON SEEDLESS PLANTED IN 1937*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
5-A	26.5	36	11.2	326	139	21.9	0.53
Salt Creek	29.0	39	14.8	390	144	21.1	0.57
Dogridge	30.1	33	9.9	304	121	20.5	0.62
1613	25.1	34	12.8	372	149	21.0	0.53
1616	29.5	38	10.9	292	139	21.7	0.55
420-A	24.6	37	11.6	322	130	22.0	0.50

* This trial is located about three miles east of the town of Kingsburg, just east of the Kings River. The soil, mapped as Delhi loamy sand, is light and porous, with a low water holding capacity. Weak, heavily nematode infested vines were removed to provide space for the test. Rootings of the experimental stocks were provided the grower in January of 1937 and field budded to the variety Thompson Seedless in September of that year, using scions obtained locally.

TABLE 3

SUMMARY OF RECORDS, 1944–1953, FOR ROOTSTOCK TRIAL IN TULARE COUNTY WITH THE VARIETY THOMPSON SEEDLESS PLANTED IN 1939*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
1616	27.3	33	8.0	243	136	23.0	0.57
Dogridge	28.8	28	6.3	225	124	22.2	0.58
Salt Creek	31.4	33	8.7	280	145	22.8	0.57
420-A	25.5	36	8.4	235	130	23.2	0.55
1613	23.8	34	8.2	238	132	22.5	0.57
Own roots	22.8	34	11.0	343	153	21.5	0.60

* This trial is located 2 miles west of the town of Exeter. The soil, mapped as Exeter loam, is quite fertile. In the location of this trial an old stream bed exists and the surface layers are of a lighter more sandy nature. Young, nematode infested peach trees were pulled prior to setting out the test. Rootings of the experimental stocks were provided by the Department and field budded to the variety Thompson Seedless, using scions obtained locally, in August of the same year.

TABLE 4

SUMMARY OF RECORDS, 1942–1952, FOR ROOTSTOCK TRIAL IN TULARE COUNTY WITH THE VARIETY THOMPSON SEEDLESS PLANTED IN 1935*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
Dogridge	30.2	37	16.5	459	141	20.0	0.63
Salt Creek	30.6	39	16.9	431	144	20.7	0.62
1616	28.9	31	13.4	404	142	21.5	0.56

* This trial is located about one mile west and two miles south of the town of Dinuba. The soil is mapped a Madera sandy loam. It, however, in the location of this trial is very light and sandy in the surface layers. The soil water table stood at two to four feet from the surface during the early years of the trial. It was lowered by improved drainage in later years. Severely weakened, nematode infested vines were removed to make space for the trial. Rooted benchgrafts of the experimental stocks were provided the grower in February of 1935. The stocks and scions were obtained from the Department's experimental vineyard. (One row of this trial was uprooted when a drainage ditch was constructed, two others were replanted with Dogridge in 1942. These rows are not included in the data above.

TABLE 5

SUMMARY OF RECORDS, 1941–1953, FOR ROOTSTOCK TRIAL IN KERN COUNTY WITH THE VARIETY THOMPSON SEEDLESS PLANTED IN 1936*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
Own roots	25.3	24	10.2	441	176	17.3	0.91
1613	28.9	25	10.5	413	177	16.2	1.05
1616	32.7	28	10.1	369	168	16.4	1.05
420-A	30.0	26	11.0	438	169	15.2	1.12
Dogridge	35.5	21	8.3	417	154	15.2	1.30
Salt Creek	36.3	20	9.5	436	162	15.2	1.34
5-A	32.3	20	9.7	460	173	15.6	1.25

* This trial is located ½ mile east of the small town of Weedpatch. The soil, mapped as Hesperia loamy fine sand, is deep and quite fertile. The surface layers in this area are loose and porous. Old prune trees, carrying an infestation of root-knot nematodes were removed to provide planting space for the trial. Rootings of the experimental stocks were provided by the Department in February of 1936 and the field budded, with scions from the Department's experimental vineyard, to the variety Thompson Seedless in August of that year.

TABLE 6

SUMMARY OF RECORDS, 1941–1953, FOR ROOTSTOCK TRIAL IN KERN COUNTY WITH THE VARIETY THOMPSON SEEDLESS PLANTED IN 1936*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
Own roots	29.2	25	13.1	522	211	16.8	0.89
1613	36.6	24	10.7	434	189	16.9	0.93
1616	34.1	23	9.6	417	179	16.2	0.99
420-A	32.7	26	11.5	433	185	16.2	1.00
Dogridge	38.7	27	12.5	449	176	15.2	1.15
Salt Creek	37.4	26	12.8	493	188	15.2	1.13
5-A	34.1	27	11.4	441	180	15.6	1.16
Own roots	27.3	23	12.9	536	218	17.3	0.98

* This trial is located 1½ miles east and ½ mile north of the town of Arvin. The soil, mapped as Hesperia loamy fine sand, is deep and fertile. The trial was set in the corner of a new planting of vines. Rootings of the experimental stocks were provided by the Department and planted by the grower in February of 1936. They were field budded, using scions obtained from the Department's experimental vineyard, to the variety Thompson Seedless in August of 1936.

TABLE 7

SUMMARY OF RECORDS, 1945–1952, FOR ROOTSTOCK TRIAL IN KERN COUNTY WITH THOMPSON SEEDLESS PLANTED IN 1940*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
420-A	22.1	24	6.4	267	152	18.7	0.82
5-A	36.1	29	8.2	305	140	15.7	1.14
Dogridge	34.2	22	6.4	246	116	16.1	1.34
Own roots	13.4	18	2.9	152	120	19.3	0.69
1613	30.5	33	10.4	322	169	16.8	1.01
1616	32.9	33	8.6	268	149	15.9	1.14
Salt Creek	33.3	28	9.2	327	151	15.8	1.24

* This trial is located two miles east of the small town of Weedpatch. The soil, mapped as Hesperia loamy fine sand is quite deep and fertile. Its water holding capacity is good. Many table grape vineyards occur in this area. Old nematode infested vines were pulled to make space for the trial planting. Rootings of the experimental stock were provided the grower in February of 1940. They were field budded to the variety Thompson Seedless in August, 1940, using scions obtained locally by the grower.

TABLE 8

SUMMARY OF RECORDS, 1941–1954, FOR ROOTSTOCK TRIAL IN MADERA COUNTY WITH THE VARIETY THOMPSON SEEDLESS PLANTED IN 1938*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
1613	18.5	24	9.0	379	138	19.5	0.55
Dogridge	24.4	30	9.2	341	123	19.8	0.62
1616	21.6	32	11.6	373	139	19.8	0.57
Salt Creek	23.7	39	15.4	423	137	19.5	0.60
420-A	21.9	29	11.1	381	133	19.3	0.61

* This trial is located seven miles south of the city of Madera and about 8 miles west of Highway 99. The soil, mapped as Ripperdan fine sandy loam, is deep and fertile. The surface layer, however, is very porous, with a tendency to blow. Old nematode infested vines were pulled to provide space for the trial. Rootings of the experimental stocks were given to the grower for planting in April of 1938. They were field budded to the variety Thompson Seedless in August 1938, using scions obtained locally.

TABLE 9

SUMMARY OF RECORDS, 1948–1955, FOR ROOTSTOCK TRIAL IN MADERA COUNTY WITH THOMPSON SEEDLESS PLANTED IN 1944*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Weight of 100 seedless berries	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)	(gm)		
Dogridge	16.3	25	6.6	278	119	21.9	0.56
1613	14.8	29	10.4	364	131	21.2	0.55
Salt Creek	19.5	33	9.9	333	134	21.8	0.58

* This trial is located about six miles south of the city of Madera and about two miles west of Highway 99. The soil, mapped as Ripperdan fine sandy loam, is deep and fairly fertile. It, however, has a loose, porous surface layer. Old, weak, nematode infested vines were pulled to provide space for the trial. Rootings of the experimental stocks were provided by the Department in March of 1944. They were field budded, using scions from the Department's experimental vineyard, to the variety Thompson Seedless in September of that year.

TABLE 10

SUMMARY OF RECORDS, 1946–1957, FOR ROOTSTOCK TRIAL IN SAN JOAQUIN COUNTY WITH THE VARIETY ZINFANDEL PLANTED IN 1942*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
Dogridge	27.6	60	15.0	257	86	203	39	E	87	21.0	0.81
Salt Creek	29.0	48	14.6	286	88	208	46	E	90	21.4	0.80
1613	20.7	33	9.2	281	94	194	47	E	92	21.4	0.66
1616	23.0	45	11.5	266	86	202	51	E	92	21.5	0.70
420-A	20.0	33	7.7	235	96	179	54	E	91	20.1	0.63

* This trial is located four miles east of the city of Lodi on Kettleman Lane. The soil, mapped as Greenfield sandy loam, is of fairly coarse structure, deep and fertile. Weak nematode infested vines in an old vineyard were pulled to provide space for the trial planting. Rootings of the experimental rootstock varieties were provided by the Department in February of 1942 and were field budded, with scions obtained from the old vines in the same planting, in September of the same year.

† Designates a purple-black berry color.

TABLE 11

SUMMARY OF RECORDS, 1945–1957, FOR ROOTSTOCK TRIAL IN SAN JOAQUIN COUNTY WITH THE VARIETY CARIGNANE PLANTED IN 1939*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
420-A	16.1	57	5.9	218	88	167	34	E	95	20.8	1.04
5-A	18.6	32	7.3	238	83	179	44	E	97	21.7	0.98
Salt Creek	20.2	43	11.1	273	88	170	44	E	95	21.1	1.04
1613	19.6	37	9.3	268	90	197	54	E	92	20.9	0.97
Dogridge	20.6	43	9.8	231	90	177	51	E	95	21.1	0.96
1616	21.3	40	9.6	235	83	179	48	E	95	21.9	0.98
St. George	21.0	46	11.7	261	88	186	47	E	94	21.1	0.97

* This trial is located one mile south of the town of Manteca. The soil is mapped as a hummocky Delhi fine sand. This is a deep loose, blow sand of only fair fertility and needing frequent irrigation. The plot was placed on land not previously planted to grapes. Rootings of the experimental stocks were provided by the Department in February of 1939 and field budded in September of that year to the scion variety Carignane with buds obtained locally.

† Designates a purple-black berry color.

TABLE 12

SUMMARY OF RECORDS, 1947–1953, FOR ROOTSTOCK TRIAL IN SAN JOAQUIN COUNTY WITH THE VARIETY CARIGNANE PLANTED IN 1943*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
420-A	9.9	17	2.0	122	78	172	64	E	86	20.6	0.87
Dogridge	15.8	34	7.9	233	75	183	60	E	87	19.0	1.06
Salt Creek	15.4	38	6.4	197	71	190	62	E	91	19.8	1.00
1613	12.0	12	4.0	174	69	181	60	E	84	19.6	0.95
1616	14.9	15	6.2	223	80	185	66	E	78	19.1	0.98
Own roots	7.3	7	0.7	103	76	140	47	E	86	20.7	0.91

* This trial is located three miles west and about 1 mile south of the town of Escalon. The soil, mapped as hummocky Delhi fine sand, is a very porous, shifting sand, with a quite low water holding capacity. Weakened peach trees, very badly affected with rootknot nematodes were pulled to provide space for the trial. Rootings of the experimental stocks were provided by the Department in February of 1943 and field budded, using scions obtained locally by the grower, in August of that year.

† Designates a purple-black berry color.

TABLE 13

SUMMARY OF RECORDS, 1941–1955, FOR ROOTSTOCK TRIAL IN FRESNO COUNTY WITH THE VARIETY CARIGNANE PLANTED IN 1937*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
Dogridge	22.3	64	13.1	220	89	149	36	E	91	19.5	0.83
1613	19.7	61	11.9	207	93	150	51	E	90	19.3	0.74
1616	20.5	68	13.3	214	89	151	40	E	86	19.7	0.78
5-A	21.7	72	14.5	224	94	147	35	E	90	19.1	0.80
Salt Creek	20.7	76	18.1	261	92	158	46	E	85	19.0	0.85

* This trial is located three miles north of the town of Fowler and near the intersection of Fowler and Central Avenues on a soil mapped as Oakley and Fresno Sands, undifferentiated. This is a deep, porous, soil, fairly fertile, but requiring frequent irrigations. The trial was set in a new rootstocked planting of vines. Rootings of the experimental stocks were provided by the Department in the spring of 1937 and field budded by the grower, using scions obtained locally, to the variety Carignane in August of that year.

† Designates a purple-black berry color.

TABLE 14

SUMMARY OF RECORDS, 1947–1952, FOR ROOTSTOCK TRIAL IN SAN BERNARDINO COUNTY WITH GRENACHE PLANTED IN 1943*

Stock	Trunk circumference	Crop per vine	Balling
	(cm)	(kilos)	
Own roots	10.8	5.1	22.3
Dogridge	26.9	16.4	23.1
5-A	22.0	11.4	23.5
1613	17.5	7.9	23.5
Salt Creek	24.6	19.5	22.1
420-A	18.3	8.3	22.0
1616	18.1	10.3	21.8

* This trial is located two miles south of the town of Cucamonga. The soil, mapped as Tujunga sand, is of a very light, porous nature. The water holding capacity is fair but the surface layer shifts or blows easily. Old, severely nematode infested vines were removed to make space for the test. Rootings of the experimental stocks were planted at the time the old vines were removed in March, 1943, and field budded, using scions from the old vines nearby, to the variety Grenache, in September of the same year.

TABLE 15

SUMMARY OF RECORDS, 1942–1951, FOR ROOTSTOCK TRIAL IN KERN COUNTY WITH THE VARIETY MOLINERA PLANTED IN 1937*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
420-A	24.1	26	11.7	457	91	338	94	B	36	14.7	0.75
1613	26.6	27	12.6	460	92	371	92	B	44	15.3	0.68
1616	30.5	25	10.3	407	86	344	90	B	38	15.0	0.81
Dogridge	32.4	24	11.8	497	96	335	99	B–	37	14.5	0.99
Salt Creek	32.9	27	13.5	522	97	332	109	B	27	13.9	0.98
5-A	32.0	21	10.5	518	95	347	96	B	34	14.2	0.97
Own roots	22.0	13	4.0	314	79	312	72	B	58	16.1	0.59

* This trial is located about one-half mile east of the town of Arvin. The soil, mapped as Hesperia loamy fine sand, is deep and fertile. The trial was established in a new block of vines. Rootings of the experimental stocks were provided by the Department in February of 1937. The stocks were field budded to the variety Molinera, using scions provided from the Department's experimental vineyard, in September of that year.

† Designates a purple-red berry color.

TABLE 16

SUMMARY OF RECORDS, 1945–1952, FOR ROOTSTOCK TRIAL IN KERN COUNTY WITH THE VARIETY RIBIER PLANTED IN 1940*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
Dogridge	21.8	33	10.3	324	85	515	180	E	66	13.7	0.73
Salt Creek	22.8	34	10.9	331	84	495	167	E	69	13.7	0.73
1613	19.1	36	9.8	285	74	517	178	E	77	15.3	0.56
420-A	18.0	35	10.0	298	88	456	170	E	68	13.4	0.61

* This trial is located two miles east of the small town of Weedpatch, in the same vineyard block as the trial listed in Table 7. The soil, mapped Hesperia loamy fine sand, is quite deep and fertile. Old nematode infested vines were pulled to provide space for the trial. Rootings of the experimental stocks were provided by the Department and planted in February of 1940. They were field budded to the variety Ribier in August 1940, using scions obtained locally by the grower.

† Designates a purple-black berry color.

TABLE 17

SUMMARY OF RECORDS, 1944–1957, FOR ROOTSTOCK TRIAL IN SAN JOAQUIN COUNTY WITH THE VARIETY TOKAY PLANTED IN 1939*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
Salt Creek	34.3	28	15.1	542	84	425	102	A	62	19.6	0.72
Dogridge	31.9	25	11.0	465	81	364	85	A	71	20.0	0.72
420-A	26.0	24	9.9	412	93	408	108	A	52	18.2	0.56
1613	28.0	26	12.5	485	93	435	119	A	60	19.0	0.57
St. George	34.3	27	13.7	509	87	418	108	A	66	21.3	0.63
1202	25.2	25	11.5	467	96	418	116	A	49	17.7	0.58
99-R	34.7	29	15.7	538	93	451	114	A	54	18.5	0.62
AxR#1	33.8	28	13.2	466	90	424	119	A	53	18.7	0.56
XX	34.3	23	10.1	437	86	430	108	A	68	19.6	0.65
Own roots	31.5	24	11.0	458	95	448	111	A	61	18.8	0.51

* This trial is located about three miles east of the city of Lodi. The soil is mapped as Hanford sandy loam. In the immediate area of this trial it is somewhat lighter and sandier than this soil type designates. Nematode-infested fruit trees were pulled to make space for the test. Rootings of the experimental stocks were planted in March of 1939. They were field budded, using scions obtained locally, to the variety Tokay in September of the same year.

† Designates a bright-red berry color.

TABLE 18

SUMMARY OF RECORDS, 1945–1951, FOR ROOTSTOCK TRIAL IN SAN JOAQUIN COUNTY WITH THE VARIETY TOKAY PLANTED IN 1940*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
Own roots	22.2	29	13.1	464	96	407	111	A	51	16.1	0.64
Dogridge	22.9	26	11.0	427	82	332	74	A−	66	16.4	0.96
1613	20.6	34	16.9	493	93	431	104	A	47	17.7	0.77
1616	22.5	34	18.5	481	87	402	106	A	56	19.1	0.86

* This trial is located three miles south of the city of Lodi and ¾ mile west of Highway 99. The soil is mapped as Hanford sandy loam. Own rooted vines had been planted in the area prior to establishment of the trial. Some nematode infestation was noted. Rootings of the experimental stocks were supplied by the Department in March of 1940 and, field budded, using scions from the Departments experimental vineyard, to the variety Tokay in September of the same year.

† Designates a bright-red berry color.

TABLE 19

SUMMARY OF RECORDS, 1944–1952, FOR ROOTSTOCK TRIAL IN TULARE COUNTY WITH THE VARIETY EMPEROR PLANTED IN 1939*

Stock	Trunk circumference	Number of clusters per vine	Crop per vine	Weight per cluster	Per cent seeded berries	Weight of 100 seeded berries	Weight of 100 seedless berries	Shade of color†	Quantity of color	Balling	Acid (gm/100cc as tartaric)
	(cm)		(kilos)	(gm)		(gm)	(gm)		(per cent)		
420-A	23.7	31	17.8	578	87	513	167	B	47	15.6	0.44
1613	27.9	28	15.8	566	84	532	164	B	50	15.0	0.47
Dogridge	30.3	30	17.9	597	79	476	158	B	65	15.5	0.48
Salt Creek	25.7	31	19.1	627	84	517	167	B	62	16.1	0.43
1616	25.7	29	15.8	517	80	484	159	B	63	16.0	0.47
Thompson Seedless	21.5	26	13.4	542	87	497	165	B	67	16.4	0.49

* This trial is located 2 miles west of the town of Exeter. The soil in this trial, mapped as Exeter loam is quite deep and fertile. The trial occurs in a newly planted block of vines. Rootings of the experimental stocks were provided by the Department in March of 1939 and budded, using scions obtained locally, to the variety Emperor in September of the same year.

† Designates a purple-red berry color.

TABLE 20

THE AVERAGE YIELD AND TRUNK CIRCUMFERENCE MEASURES ON STOCKS IN SEVEN TRIALS WITH THOMPSON SEEDLESS*

STOCK	Plot 1 Tulare County		Plot 2 Tulare County		Plot 3 Tulare County		Plot 5 Kern County		Plot 6 Kern County		Plot 7 Kern County		Plot 8 Madera County		Totals	
	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)
1613	27.9	16.0	25.1	12.8	23.8	8.2	28.9	10.5	36.6	10.7	30.5	10.4	18.5	9.0	191.3	77.6
Dogridge	33.3	13.9	30.1	9.9	28.8	6.3	35.5	8.3	38.7	12.5	34.2	6.4	24.4	9.2	225.0	66.5
Salt Creek	32.7	13.1	29.0	14.8	31.4	8.7	36.3	9.5	37.4	12.8	33.3	9.2	23.7	15.4	223.8	83.5
1616	30.4	15.0	29.5	10.9	27.3	8.0	32.7	10.1	34.1	9.6	32.9	8.6	21.6	11.6	208.5	73.8
5-A	..	...	26.5	11.2		....	32.3	9.7	34.1	11.4	36.1	8.2	...	....	...	...
420-A	29.4	16.4	24.6	11.6	25.5	8.4	30.0	11.0	32.7	11.5	22.1	6.4	21.9	11.1	186.2	76.4

* For trunk circumferences—Standard Error of totals at 5% level = 15.60.
For crop per vine—Standard Error of totals at 5% level = 19.37.

Table 21

THE AVERAGE CLUSTER WEIGHTS AND BERRY WEIGHTS WITH THOMPSON SEEDLESS IN SEVEN ROOTSTOCK TRIALS*

STOCK	Plot 1 Tulare County		Plot 2 Tulare County		Plot 3 Tulare County		Plot 5 Kern County		Plot 6 Kern County		Plot 7 Kern County		Plot 8 Madera County		Totals	
	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)
1613	546	178	372	149	238	132	413	177	434	189	322	169	379	138	2704	1132
Dogridge	474	136	304	122	225	124	417	154	449	176	246	116	341	123	2456	951
Salt Creek	507	153	390	144	280	145	436	162	493	188	327	151	423	137	2856	1080
1616	471	158	292	139	243	136	369	168	417	179	268	149	373	139	2433	1068
5-A	....	....	326	139	....	....	460	173	441	180	305	140	....	....	....	....
420-A	477	154	322	130	235	130	438	169	433	185	267	152	381	133	2553	1053

* For cluster weights—Standard Error of totals at 5% level = 215.17.
Standard Error of totals at 1% level = 356.35.
For berry weights—Standard Error of Totals at 5% level = 73.3.
Standard Error of Totals at 1% level = 121.6.

TABLE 22

THE AVERAGE YIELD AND TRUNK CIRCUMFERENCE MEASURES ON STOCKS IN FOUR WINE GRAPE TRIALS*

Stock	Plot 10 Zinfandel San Joaquin County		Plot 11 Carignane San Joaquin County		Plot 12 Carignane San Joaquin County		Plot 13 Carignane Fresno County		Totals	
	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)	Trunk circ. (cm)	Crop/vine (kilos)
1613	20.7	9.2	19.6	9.3	12.0	4.0	19.7	11.9	72.0	34.4
Dogridge	27.6	15.0	20.6	9.8	15.8	7.9	22.3	13.1	86.3	45.8
Salt Creek	29.0	14.6	20.2	11.1	15.4	6.4	20.7	18.1	85.3	50.2
1616	23.0	11.5	21.3	9.6	14.9	6.2	20.5	13.3	79.7	40.6
5-A	....	....	18.6	7.3	....	....	21.7	14.5	....	....
420-A	20.0	7.7	16.1	5.9	9.9	2.0	16.1	9.8	62.1	25.4

* For trunk circumference—Standard Error of Totals at 5% Level = 10.94.
For crop/vine—Standard Error of Totals at 5% Level = 9.44.

TABLE 23

THE AVERAGE CLUSTER AND BERRY WEIGHTS WITH WINE GRAPES IN FOUR ROOTSTOCK TRIALS*

Stock	Plot 10 Zinfandel San Joaquin County		Plot 11 Carignane San Joaquin County		Plot 12 Carignane San Joaquin County		Plot 13 Carignane Fresno County		Totals	
	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)	Cluster wt. (gm)	100 Berry wt. (gm)
1613	281	194	268	197	174	181	207	150	930	722
Dogridge	257	203	231	177	233	183	220	149	941	712
Salt Creek	286	208	273	170	197	190	261	158	1017	726
1616	266	202	235	179	223	185	214	151	938	717
5-A	....	....	238	179	....	....	224	147	....	....
420-A	235	179	218	167	122	172	174	136	749	654

* For cluster weights—Standard Error of Totals at 5% Level = 144.4.
For berry weights—Standard Error of Totals at 5% Level = 58.6.

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